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ABSTRACT

This article was originally written on the internet in Australia to provide a starting point for discussions of new perspectives on education made possible by advanced technologies. Ecosocial changes in the practices and institutions called education are discussed in the context of changes in the practices and institutions called information technologies. The fundamental assumptions of academic education are incompatible with the present, much less the future, needs of postmodern society; and schooling is not likely to continue as the dominant form of education. By the end of the next century, scholarly work will be incomplete if it consists of written text alone. It will diverge to multimedia hypertext and then to virtual realities in cyberspace. Libraries will exist in cyberspace, and they will contain all electronically stored information that is publicly accessible. The research questions of the future will increasingly be about how people will educate themselves in cyberspace. Educational theory will deal with a multitude of new issues concerning teacher and student roles. The potential roles of cyborgs and ecocybersystems are discussed with regard to virtual reality. In cyberspace, we will be able to see virtual reality worlds, and children will have experiences that will not lead them along the cultural paths of the past. We must begin to work our way toward these developments in education of the future. (Contains 29 references.) (SLD)

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EDUCATION, CYBERSPACE, AND CHANGE

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INTRODUCTORY NOTE

This article was originally written to provide a starting point for discussions of new perspectives on education made possible by advanced technologies. That discussion was conducted as an "electronic salon" on the internet organized by Chris Bigum and Bill Green of Deakin University in Australia in conjunction with a major conference held there in 1992. The perspective and style of the contributions was explicitly post-modernist. Some minor changes have been made to make this version more accessible to a wider readership.

A FRAMEWORK: ECOSOCIAL DYNAMICS

The functions of scholarship are not limited to the production and validation of new knowledge and new theoretical perspectives. As scholars we also have a responsibility to articulate the social and cultural changes that new developments make possible, or even conceivable. These are not predictions, they are options; and we must argue for them on the basis of value choices as well as factual determinations and theoretical interpretation.

We have only a very limited repertory of metaphors for change. Change is most often spoken of in the language of movement. Whether as the progress of forward movement, retrogression, circularity, or the dialectic of `two steps forward, one step back', all these metaphors embody a deceptive semantics in which change seems voluntary, like walking, in which all directions seem equally "there" in principle, in which past steps determine where we are but not where we go next, and in which there is always "somewhere" to go to.

Scientific discourses are not immune to these ways of talking (classical physics carries them to their utter limits), but they have evolved in highly specialized contexts alien to common experience. In their spectrum of divergence from common sense, they have elaborated some useful new metaphors for social and cultural change. I have described these in detail elsewhere and suggested their possible usefulness for models of cultural dynamics (Lemke, in press). Here I will only brief-

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ly sketch a few of these which I plan to use as a framework for this discussion.

Organic growth is another possible metaphor for change, very different from the metaphor of motion. It belongs to a family of metaphors for the dynamics of complex systems that includes embryological development, ecological succession, biological evolution, and the postmodern physics of so-called chaotic systems (more specifically the nonlinear dynamics of systems with complex webs of internal self-coupling among their constitutive processes). These sorts of systems share many dynamical features, and they have also been described generically as autopoietic, self-organizing, or non-equilibrium dynamic open systems (see Lemke, in press, and references therein, especially Salthe 1985, 1989; Harrison 1982; Odum 1983; Jackson 1989; Prigogine 1980, 1984 also cited below; less technically, on chaotic systems, Gleick 1987). They include hurricanes, rainforests, cities, and organisms, as well as stars, flames, and even dripping faucets. In all cases the system is never a NOW, it is always a TRAJECTORY of development over time. It is not the butterfly, but the larva-pupa-butterfly trajectory; not the person-now, but the zygote-embryo-child-adult-dotard trajectory.

The trajectories of particular systems follow an average type-trajectory of development for their kind, modulated by individuations. The type-trajectory for the kinds of systems we are interested in cumulates and modifies over generations; it evolves. Evolution takes place when some initially unique individuation becomes typical, and that happens, interestingly, when latent possibilities for divergence along the trajectory (potential side-routes not previously taken) are activated by novel environments. Once the developmental trajectory has evolved to follow a particular series of stages, changes in the later course of development require divergences earlier than the last relevant branching point, or bifurcation. One consequence of this is that children, in the course of development, can potentially advance cultural evolution, precisely insofar as they do NOT recapitulate all the stages of intellectual development of the previous generation. The earlier the divergence, the more profound the possible changes in how the trajectory may ultimately develop.

It is probably fundamentally wrong to imagine that the way to "progress" is to educate each generation up to maturity to be exactly like its predecessors, and then expect them to radically innovate. That model is a recipe for inhibiting social and cultural change. Encouraging children to do the bizarre, the unthinkable, the immoral, and even the impossible, would probably not rock social stability more than a very little bit, but it could produce individuations that history (i.e. the rest of us and our successors) would ultimately edit into fundamental sociocultural change.

Another basic lesson of these models of postmodern dynamics is that it is SYSTEMS that develop, and that systems are always systems of interdependent processes and activities (not aggregations of interacting "things" or "persons" as such). The trajectory-system for which one

can formulate a dynamics is always a bit arbitary in its boundaries, because to exist it must transact with a sustaining, conditioning environment, together with which it forms a supersystem on a larger scale, just as it is constituted in turn of interacting subsystems at smaller scales. All dynamical analysis must be ACROSS SCALES (of time, space, energy-transfer, information-transfer) as well as over the durational, or trajectory "time" that these processes themselves engender.

So it is again fundamentally wrong to imagine that human social systems have an autonomous cultural dynamics; they cannot. Human social systems are inextricably interdependent with (and in many cases coextensive with) systems of material processes that include the physical-chemical-biological ecosystem (both its biotic and abiotic components), up the scale hierarchy, at least to Gaia (the planet as a quasi-living, and conceivably quasi-conscious system; cf. Lovelock 1989), and probably beyond. Cultural practices are always also material processes; they construe meaning and assign valuation, but they also participate in eco-physical couplings (as well as in systems of purely semiotic relations) and co-evolve over time as parts of a larger, unitary "ecosocial system" (Lemke, in press).

My concern in this paper is with ecosocial change, with changes in the practices and institutions we call education in the context of changes in the practices and institutions we call information technologies. But both these foci must be embedded in much larger and more complex systems, if we are to truly imagine the nature of likely and possible changes.

DEVELOPMENT UP TO NOW: SCHOOL v. CYBERSPACE

Ecosocial dynamics readily accommodates the classic principle of "uneven development", i.e. within the same system, at the same stage of overall wide-scale development, different subsystems will have followed different trajectories of local-scale development, and the system as a whole will be "patchy": a mosaic of elements that show diversity of every sort, including the co-existence of contradictory elements, often from different periods of evolutionary history. In the same city you will find architecture, and even plumbing, from different decades and different centuries, side by side. In the same system of personal semiotic practices you can find a monarchical religion, a bourgeois economics, a classically socialist politics, and a postmodern epistemological stance, all happily co-habiting. In our postindustrial societies you can find on-line database technologies and textbook-based schooling.

Schools as we presently understand them hardly existed much before the 19th century, and it is hard to imagine that they will continue to exist in any recognizable form by the end of the 21st. All social institutions, as part of their legitimization, endow themselves with an aura of perpetuity. Modernism imagines that what are in their origins

essentially 19th century bourgeois institutions continue to be infinitely flexible and adaptable, their principles so inherently correct that they will continue to serve useful functions in all possible futures, forever and ever, world without end (_pace_ Ozymandias).

The fundamental assumptions of academic education are incompatible with the present, much less the likely future needs of a postmodern society. Schools will continue to exist in patches, but they will grow sparser, less relevant to the system as a whole, to its futures. This trend has been evident at least since the 1960s, when anti-establishment views had a substantial hearing (e.g. Illich, 1971). The dominant information technology in the Age of Schooling was the printed book. The technology advanced until large numbers of books could be had at reasonable cost by large numbers of people (subsidized by the death of forests, the toxic pollution from paper mills and synthetic inks). This information availability made read-only print literacy a cultural practice of gradually widening social value to individuals and institutions. Schools were instituted to teach reading, and with textbooks came curricula that, in principle at least, still consist essentially of learning to read one subject-specific register or another. Academic examinations are basically tests of what is supposed to be read in textbooks.

Schooling today is a full-service institution. Like the family, it serves a multitude of economic, social, political, and ideological functions. But as a mode of education, it still relies heavily on its assumption that education is about reading textbooks. Apart from some areas of higher education, textbooks (i.e. books written for and read only by school students and their teachers) are pretty much all that is read in schools. Textbooks are the specialized technology of print publishing for selecting and organizing a very small subset of all the information around. Great political (and pseudo-intellectual) battles are waged about what gets into them, and how much of it.

The currently dominant ideology of curricular selection and priority holds that there are, in every subject, certain key abstract concepts which once "grasped" by students, can then be transferred or applied to novel situations throughout the rest of their lives. Postmodern, semiotic constructivist epistemologies undermine the logic and the interpretations of evidence for this older theory (see, e.g. Lave 1988, von Glasersfeld 1991; Lemke, forthcoming), which in retrospect seems not much more than a rationalization for the academic status quo.

People learn to do things by DOING them; not by talking about concepts abstracted from doing them. What we actually do learn in school is simply what we DO in school. The fact that academics can construct post-hoc similarities between school activity types (semiotic practices) and those in the rest of human life does not imply that developing individuals will automatically reconstruct the historically contingent ways in which their culture has decided that two distinct activity types involve applications of "the same" concept. It is only AFTER we have learned new activities that we can be taught to con-

struct their "similarity" to prior activities, according to the conventions of our particular culture and community.

Schooling is starting to unravel. Schooling is reverting to the oral tradition from which it began: the teacher reads the textbook and gives an oral exposition of its contents, sometimes in dialogue with students. Fewer and fewer students actually read their textbooks, or learn how to construct meaningful discourse patterns by doing so. Students have other sources of information now about the amazing, horrifying, and often dangerous world in which we live. Sources whose content is more convincingly relevant: television programs and movies (with a residuum of comics and magazines). Video sources are oral and visual; they do not require print literacy.

These sources are well-adapted to convey startlingly novel information through sensory-interpretive channels that are (unlike print literacy) evolutionarily old, and whose use is second-nature. Those channels have been extended; you have to learn how to see video, it is a highly conventionalized semiotic medium. Its verisimilitude is only the sign of its success in accessing/extending the old channels. The rule of ecosocial change is: one step back in order to go two steps forward (_reculer pour mieux sauter_; retrogressive re-potentialization). Back from print literacy to oral-visual communication in order to go forward to video, cyberspace, and virtual realities.

Today's students have already diverged, in interaction with video media, from the developmental track (as much a cultural as a biological one, clearly) that formerly led to print literacy. This same divergence is one that better prepares them, compared to previous generations, for what is coming next. That is how typical developmental trajectories evolve.

I am not predicting the demise of written language in the near future; but it will be fused ever more closely with other semiotic modalities of communication and representation. We used to wean children away from picturebooks. Adult books, scholarly books needed no pictures. Back one step: scholarly work, by the end of the next century, will be considered incomplete if it consists of written text alone. Forward, diverging, two steps: to multimedia hypertext, and then to virtual realities in cyberspace.

I am arguing that schooling is not likely to continue to function as the dominant form of education, certainly as the dominant mode by which society makes available what it considers important information for society-wide dissemination. Illich (1971) long ago argued that schools could be replaced by libraries as the dominant educational institutions. Libraries, of course, will themselves be very different by the time this has happened (my guess: 50 years).

Libraries will exist in cyberspace, and they will contain, not printed text-only books, but all electronically stored information which is publicly accessible. They will, unfortunately, probably no longer be

free, though it might be worth fighting for this. For a fee, more will be accessible. The library will merge with the bookstore, and both with the electronic database, which will hold not just text and numbers, but pictures, graphic representations, videos, music, and virtual realities. Television, telephones, and computers will be absorbed into the new institution as well (while continuing to exist independently in the patchy way of uneven ecosocial development).

In embryo, all this already exists. Any inexpensive computer, with another $50 for a telephone modem connection, can already link to a worldwide amateur network (Fidonet) of bulletin-board systems (BBSs) that are pioneering the cultural practices which establishment institutions (the Internet) will follow, just as the "Ham Radio" of the 1950s pioneered the Global Village long before sattelite television. BBSs are themselves often run on very inexpensive, jury-rigged computer systems. And they already have graphics, and music, and CD-ROM on-line. Video and virtual reality (VR) await only the fiber-optic cable network (or digital telephonics, or super data-compression schemes) that will replace present telephones lines and television (broadcast and cable, picturephones and HDTV). Japan will have it first, thanks to being younger as a technological society (its trajectory individuating in more modern/postmodern conditions) and having been pushed "one step back" in WW2.

Neoteny is extended immaturity, and hence prolonged capacity to diverge developmentally (cf. Gould 1977, Montagu 1981). College students, and adventurous faculty, have already discovered that even the primitive Internet can get you access to vast libraries of world-diverse information (though mainly only text and numbers yet; pictures are just arriving). This capacity will grow exponentially in the next few years. Younger "hackers" discovered 10-20 years ago that a little innocent larceny could get you into even the proprietary databases of corporations and governments. Not textbooks, but authentic information in its customary forms. Not what someone else thinks you should know, but what you choose to find out. Not one controlled version of the truth, but as many versions as you care to examine. Not a test to evaluate whether you have learned the content of the textbooks, but value judgments about the worth of whatever it is you have learned. By you, by others; for specific, definable purposes.

In our lifetimes, in the lifetimes of our students, and their students, people will learn what they need to know by accessing global electronic databases, and local proprietary databases, that will contain the totality of available information, in forms that will organize that information, or allow us to reorganize it, into whatever forms may be most useful for our immediate purposes. The successor to print literacy will be the set of skills needed to locate and usefully organize information, for ourselves and for others, in cyberspace. (For further discussion, see Lemke 1993.)

What we today marginalize as "informal education" (museum displays, library use) and auto-didacticism will become tomorrow's norm; formal

schooling will become rarer and more old-fashioned. It is already impossible to convincingly justify any particular selection of information as THE curriculum. Recent efforts to do so have either been reactionary attempts to return to the curricula of pride and prejudice, or else fanciful flights of abstraction seeking to teach non-existent, universally applicable intellectual processes (pseudo-universal problem-solving skills, higher literacy skills, etc.). Both essentially deny the diversity of human experience and seek to substitute for it impossible claims of universality.

There are no useful universals. Universal claims are always either parcchial power-plays or abstractions of so high an order as to say almost nothing about individual instances. Where them seem to do so it is only because they conceal critical instance-specific information in the unacknowledged procedures for linking abstractions to instances (more obvious when we remember that an abstraction is itself only a set of procedures for linking instances to other instances). There will be no common curriculum in the future, except what is artificially maintained by political power. Education will not be the foundation of a common global culture; only shared technologies will interface between diverse communities. Each local community will be less stable because of this, but the global community will be better able to survive and prosper.

People will create for themselves and others unique and distinct educations. Each person will be knowledgeable about some particular collection of topics and practices, accumulated along their biographical trajectory; people will communicate and collaborate in shorter- and longer-term communities, distinguishing less and less between those we today call "real" or "virtual". Many people will be "experts" in esoteric interests of varying value to others. They will share those interests and their expertise with those who come looking for it or are willing to barter for it, as suits them or as they need. This information-culture-cum-barter-economy already exists among the BBSs and on the USENET and specialist conferences of the Internet.

EDUCATION IN CYBERSPACE: THEORETICAL ISSUES

We have arrived at a moment when research on education in schools has limited usefulness for the human future. Just as there was a time when research on horse-drawn carriage design, or vacuum-tube circuitry, gave way to automotive engineering and solid-state electronics, so the future research questions of education will increasingly be about how people will educate themselves in cyberspace.

Educational theory has resisted this shift, not surprisingly. We can claim, against traditional CAI, that human social interaction is a necessary element of education, but cyberspace will be a virtual place FOR human social interaction. We can claim that people interact with other people in fundamentally different ways, probably necessary for learning, from how they interact with artefacts and natural objects,

including today's computers. But we also know that people can learn in additional ways if a base of social learning is provided: by observing, by listening, by reading, by video viewing, by manipulating objects, by experimenting, by writing, by drawing, by calculating, etc., etc. And in cyberspace all of these, and more, will be available. You could even re-create virtual classrooms in cyberspace (though hopefully only for databases on the history of schooling).

Educational theory now has to deal with new issues:

What IS a teacher? What features would a program, an artificial intelligence, in cyberspace have to have to fulfill the various essential functions of teachers? What features will tend to cue students to interact with the AI as if interacting with a person rather than an object? How, precisely, do people, in fact, now interact differently with other people than they do with artefacts like books, pictures, museum displays, and computer programs? And how do they consequently learn differently?

These questions begin as the direct extension of such simple present-day questions in CAI as what sort of helpfiles should be provided to students, or how best to design an on-line tutorial for the use of an application system. Granted that we are still some years away from AIs that will be able to flexibly dialogue in natural language (10-20 years), the identification of what such systems will need to do to function as tutors is a present problem. Long before such AI tutors exist, there will be sophisticated instructional systems that will show users what can be done with an application, what knowledge is available and how it can be accessed, manipulated, and transformed, where to get further information on specific topics, etc. When natural language AI tutors appear, they will represent only incremental change.

How do students at various levels of experience explore large databases? What are their strategies? What sorts of assistance would make it easier for them to pursue these strategies? How do the strategies shift in the presence of various facilities? How can access to databases be made more natural (i.e. easier to execute by extensions of evolved human capacities for, say, spatial exploration, or verbal metaphoric association)?

How do people co-organize information in multiple semiotic modalities (spoken language, written text, sound-music, diagrams, photo images, video sequences, spatial movements, tactile and other sensations, object manipulations, social activity sequences, etc., etc.) to produce complex "presentations" for themselves and others, for various purposes?

What sorts of action environments would people construct to try out various imaginary action possibilities (simulations, experimentation, social interactions, etc.)? And what sorts of action environments should be made available to facilitate learning various sorts of cul-

tural practices? This is rather like the classic "learning environments" or "learning activities" problem in educational theory, except that in cyberspace one is no longer limited by the physical classroom and its resources. While it will be a long, long time before cyberspace virtual realities will have anything approaching the complexity of interactional possibilities of material realities, they will quickly exceed those of the average school classroom. Cyberspace will be a convenient place to practice for, and review recordings of, participation in material social settings and activities. Education will take place partly in cyberspace and partly by direct participation in social practices. Both will be superior to classrooms, as experience with clinical-practical education and realistic simulations has long shown.

What should be the hierarchy of referral of student/user queries? to on-line helpfiles, AI database systems, expert conferences, peer conferences, human tutors, AI tutors, etc.?

What should be the function of full-presence VR (or material co-presence) group interactions? i.e. when and why should students and human tutors either physically meet to dialogue and work together or meet in cyberspace as if fully physically co-present? What can be accomplished in this way that cannot be by any of the other available modes of social interaction in cyberspace? (One interesting possibility is that of being able, at will, to re-view a scene or a datascape from the perspectives, visual and conceptual, of another participant.)

How can systems be provided that will enable people to test their mastery of various topics and practices? Will this be necessary? Will some cyberspace conferences, for example, only be open to contributions from people who meet certain criteria? There will probably be a vast testbank, each of whose test systems will be recognized by varying numbers of institutions. It is as likely that a person would submit a list of tests they had passed, and the tests then be evaluated as establishing criterial equivalencies, as that they would be asked to submit to a specific test. It is also possible that resumes and individual educational portfolios, would prove more useful and valid than tests for such purposes, once methods of automating the application of various sets of criteria to the same portfolio are developed. The portfolio is in effect a personal-accomplishment database, subject to query and evaluation for many possible purposes, according to many possible value schemes.

CYBERSPACE AND VIRTUAL REALITIES

What IS cyberspace? The answer, to the extent there is one, makes more sense with a first understanding of the technology of virtual reality (Rheingold 1991; Benedikt 1991). VR is, most fundamentally, a type of interface between humans and computers. Just as typing at a keyboard replaced submitting punched "IBM cards" and looking at a screen re-

placed reading "printouts", just as the mouse and the point-and-click graphics screen (and soon the pen-stylus) changed this second interface still further; so, in the next full generation of change, the computer will sense our head- and hand-positioning and show us 3-D images. When the 3-D image fills our field of view and automatically shifts in real time as we shift our gaze or move head and shoulders, a remarkable effect occurs: the sense of presence in a virtual, computer-generated reality.

This sense of presence derives from the evolutionary adaptations that make us feel at home "in" material reality, that make our state of internal neurological activity "feel" like there is a real, external world around us. This sense is enhanced by the ability to move around in this world (and have it seem to correspondingly shift around us as we do so) and to affect it, mainly by physical actions of touch. It is the COUPLING between efferent, active nervous activity and afferent, perceptual signals that we interpret as being in a real external world. It is the ADDED INFORMATION at the point-of-turnaround between efferent and afferent, the contribution our bodies do not normally signal as coming from "us," that we learn culturally to interpret as an "other," real on the same order as we feel ourselves to be real. When the computer mediates between our actions and our perceptions, the nervous system and its cultural programming interpret this as an external reality and provide us with a sense of presence in this "virtual" reality.

A virtual reality is then a possible world, as real to the senses and responsive to actions as the material world, but more protean. It is a domain where magic works, where a word or gesture can change local reality, much as now a click of the mouse can transform a graphic image on the screen. Anything semiotically constructable can exist in virtual reality. Any semiotically constructable transformation can take place in virtual reality. And virtual reality can be semiotically, and physically (analogue coupling inputs), coupled to material reality, so that it can constrain our possible constructions in ways that will work outside VR as well as inside it. But in VR we can decide in just which ways we will allow it to constrain us.

Through VR we can explore databases collected in interaction with material phenomena, and we can operate remote robots in the material world, seeing through their eyes, being where they are, acting with their effectors. We cannot move the robots instantaneously from site to site, but we can move our own sense of presence from robot to robot with a word, or a glance. We could also turn around and look, from a new viewpoint, at ourselves.

We can limit ourselves to the possibilities inherent in a set of material-world data, but we can also learn to understand that data better by altering it and seeing, from the inside, how the world the new data describes would then be different.

Material-world data will include 3-dimensional recordings of human activities and events that we can enter, move around in to see from any

point-of-view, touch, and manipulate in every conceivable way, as data. They will also include recordings of phenomena never before experienced by human beings, transduced for human senses. And through VR interfaces, and remote effectors, we will be able to act on phenomena in places and at scales, where the sense of human presence has never gone before.

Cyberspace is the space of interactive computational possibilities. It is, in one sense, a network that makes all participating computers and their accessible contents (data, programs) available to the users of any participating computer, anywhere. It means that all the information on earth and every strategy for transforming information ever conceived anywhere are in principle available to every user all the time. It is not just a storage space, it is a space in which you can do things. You can create, or borrow, a virtual room, and meet other users there face-to-face, body-to-body, (realistic or fantastic) virtual-image to virtual-image. You can move around in this room; you can touch and feel virtual people and things. You can create images, sounds, language, objects, people, actions, events, from recordings of material reality or by direct construction ex nihilo. You can expand the room, or shrink it, change your viewpoint by "flying" above it, or below it.

If it proves the case, as many people now believe, that humans can better navigate in search of cyberspace resources (databases, programs, specific computers, users, conferences, etc.) when these are represented in a visual-spatial way, then there may come to be, in the Network, a standard CYBERWORLD where computer nodes appear as spatially separate boxes or fanciful shapes coded to their types (supercomputers, corporate systems, BBSs, PCs, etc.) in distinct locations, where users' addresses have virtual spatial locations, where databases and other resources are visible as in a 3-D map, where there are signposts or other systems to help you find your way around, where proprietary data is guarded, or hidden, and where there are Worlds within Worlds at various scales (fractal cyberspace). This master CYBERWORLD will be cyberspace in another sense, or at least its standard VR representation.

Ultimately, cyberspace is what you can do in it, the space of possibilities for computation and interaction, for the creation, storage, and transformation of information -- in a domain where everything meaningful is information. VR simply makes cyberspace feel familiar to the learned extensions of our evolved human capacities for perception and action.

CYBORG EVOLUTION: ECOCYBERSYSTEMS AND SURVIVAL

Can a community learn? Can a species? Do we educate societies as we do individuals? If so, what are the implications of cyberspace technology for education in this larger sense?

"Education" and "learning" are rather old-fashioned ways of talking about some aspects of developmental processes of individuation in dynamical systems. These processes, for individual human organisms, are "epigenetic' (Waddington 1957, 1969; Lemke 1984, in press), i.e. they are processes in the development of more inclusive systems that must be defined across many scales from our DNA and its biochemical interactions with a cellular and organismic environment to our human-scale semiotic and material interactions with other humans and with the rest of our ecosocial environment.

The individual organism is not a sufficient substrate system to discuss even "learning," much less "education". "Learning" is not a process that takes place INSIDE the system we call a human organism; its semantics is highly misleading. People do not learn. Learning is not an internal process. People participate in larger systems and those larger systems undergo developmental processes; in interaction with their own relevant environments, they create the conditions for their own further change along evolved, type-specific and individuating trajectories. Some things change inside people as they participate in these processes, and other, internal developmental processes of the same kind are going on within us among our own subsystems, coupled to our participation in these larger processes. What fundamentally changes, what we call learning, is how people interact with and participate in the larger ecosocial systems that sustain them.

Learning is, consequently, neither a "mental" nor a "cognitive" process (cf. Thibault 1986, Lemke 1989, Geertz 1983), unless we view cognition and the mind as themselves essentially interactional processes extending beyond individual human organisms -- as social and transactional phenomena, in which individual brains and bodies participate, but which do not take place "in" individuals, but only between them and their ecosocial environments (cf. Cole et al. 1971, Cole & Scribner 1974, Lave & Rogoff 1984, Lave 1988).

What then can it mean for a COMMUNITY to learn? Simply that it participates in a still larger ecosocial system and undergoes development in interaction with it. The community learns in the sense that its ways of interacting with the larger system, and some aspects of the internal interaction of its constituent subsystems (e.g. of individuals, but more basically of the activities and processes in which individuals participate), change. Of all the possible kinds of developmental change, we tend to call only those learning which exhibit increased complexity of response, an enlarged combinatorial space of action possibilities, and an increased long-term adaptedness to the environment. Development in general, of course, also includes senescence, also includes fatal innovations.

A species is a type. An organism, or a community, belongs categorially to some type, inheriting characteristics shared with other systems descending from the same lineage, but is a token of the type, an instance of the category. Tokens develop. Types evolve. The evolutionary trajectory of a type is an envelope of the successive developmental

trajectories of its tokens over generations (Salthe 1985, 1989; Lemke, in press). Tokens individuate in development, becoming unique while staying somewhere in the vicinity of the average developmental trajectory characteristic of their type. When that average changes, as a result of systematic shifts in the individual development of tokens over generations, we say that the type has changed, has evolved. Species learning is thus an evolutionary process.

Once again, however, learning is not a process internal to the species. Species co-evolve as components of ecosystem-types. Just as individuals do not learn, so neither do species. But just as individuals participate in the developmental processes of larger ecosocial systems, so do the type-specific behavioral trajectories of species evolve along with the ecosystem types in which they participate. The notion of a species, however, while formally just a synonym for type, has tended to mean a type of individual organism, and that, as we have seen, is not the right unit of analysis for education, unless we treat it transactionally. What a species learns in evolution, if anything, is how to participate differently in its ecosystem-type, how to relate differently to its typical environments.

It is fashionable today to speak of "cyborgs". This metaphor (e.g. Haraway 1991) reminds us that we are not just organisms, we are organisms constituted by our interactions with our environments, and increasingly those environments are artefactual. We are made by doing-with, and the things we do-with include computers, video, and all the other tools of our technologies. There are not simply humans on one side and machines on the other. Humans are shaped by their interactions with machines just as machines are shaped by their interactions with humans. The appropriate system level for analysis is the human-machine system, the cybertech-organism system. But the notion of "cyborg" does not go far enough. It retains the limitations of the romantic notion of autonomous individuals; a cyborg is just a different sort of individual. We speak of it still in the language, the metaphors, the semantics appropriate to human individuals.

The meaning we need to make is a dialectical synthesis of the notions of cyborg (unitary machine-human individual) and of eco-social system (unitary material-semiotic, ecological-social community). We need a notion for a system of material-processes-that-are-also-sometimes-semiotic-cultural-practices, rather than a system of individuals. We need a notion of system as token, not type. We a notion of a system within which individuals are constituted, and which is itself constituted in part by the actions of individuals. And, for present purposes, we need to foreground the role of cyberspace technology in these processes.

Ecocybersystems. ECS.

How do we expect ecocybersystems to develop in the near future? What changes in how humans participate in the larger ECS will this entail? What possibilities for the future of humanity, of the planet, of ECSs

and wider ecosocial systems are we making as we participate in newly developing ECSs?

For those still more comfortable with the older metaphors:

How will cyborg experience change what it means to be human? Will cyborg children learn to feel new connections with the ecosystems that sustain them, as well as with the technologies that entrance and enhance them? Will human culture evolve ethically and politically in the cyberspace environment to accept a more mature responsibility for the survival of a rich and diverse ecology on our planet and perhaps others? Will we learn to identify with Gaïa and her sisters, to make their/our interests humanity's highest value principle?

The highest good which discourse can frame is not the good of the individual, nor of the family, the tribe, the city, the nation, or even of humanity, but the good of the Whole. Humanity will live or die as part of the Whole. Human cultures must evolve toward Gaian values that put ecosystem interests above human interests, and value other species and even abiotic systems for their contributions to the Whole, rather than their contributions to our own small part of that Whole. Or someday soon there will be no human cultures.

How will human development in cyberspace, humanity's participation in ecocybersystems, educate individuals, communities, and finally, one hopes, our species to interact differently with the rest of the Whole in which we have our being?

One existing VR prototype system (Rheingold 1991: 26-45) allows the user to see and touch human-scale 3-D images of large biological molecules. The complex spatial conformations of these molecules determine how they interact chemically (and vice versa). Users can manipulate the molecules as if they were human-scale objects, jockeying them to see if they can be fit together as needed. They can modify a synthesizable molecule to see if it will fit better to function as a therapeutic drug. All the evolved skills of hand-eye coordination can be used to augment theory-based imagination of possibilities. New hand-eye coordinations are learned to handle the unfamiliar computer-transduced responses of intermolecular forces, and potentially even quantum effects. The human user is changed by participating in a world that responds differently to human action. The prototype is not a full-immersion VR, it has only a weak sense of presence, though a strong sense of the reality of the VR molecules and their behavior. How will humans be changed when they develop with frequent full-presence experiences in the world of molecular-scale forces?

Children will one day grow up playing not just in the Nintendo world, but in full-presence worlds where the laws of VR nature correspond to those of quantum forces, the behavioral codes of other species, and phenomena from vastly different scales of time, space, and energy than humans have ever experienced in the past with the vividness of full-presence VR. Their developmental trajectories as part of ecocyber-

systems will diverge early and far from past norms, down many new pathways. This development is not simply a biological process. It is simultaneously a development of systems of cultural and semiotic practices, activity types for individual interaction with VR and material environments. And it will be a developmental process of and in a community, shared by many individuals.

In cyberspace we will be able to see VR worlds, and recordings of and real-time sensor inputs from World-One, in infrared, microwave, and x-ray bands of a newly visible spectrum. We will be able to hear at all frequencies, from the echoes of earthquakes and the songs of whales and insects, to the resonances of crystals. We will be telepresent with probes on Mars and on the deep-ocean floor, we will be able to walk the Martian plains, kick lunar dust, sound with whales. We will be able to float above the earth at any elevation, seeing in any spectrum, observing cities or rainforests in real-time or watching the changes of days or years go by in minutes, or seconds. We can live at the pace of a tree or a forest, a hurricane or a glacier, a cell or a molecule. We will do all this as children. We will not develop along the same cultural paths as in the past.

Hopefully, we will bring these same technologies to the study of the social and cultural components of our ecosystems. The life-histories of cities, the patterns of economic flows, the changing distribution of wealth and consumption of resources, the incidences of violence, the prevalences of weapons, the development of movements in art, the evolution of genres in literature, the histories of languages, the heteroglossia of discourses, the evolution of technologies.

I cannot foresee how these experiences will change us, will change how we participate in the larger systems of which we are a part. But I hope that, in expanding our experience beyond the realm of the human-scale, of local information and local concerns, we will learn to FEEL what it means to participate in the Whole in ways other than those that have been traditionally thought human. We can do this by extending our evolved capacities to feel and act in a world. I hope that in roaming the many worlds of the Whole, in learning to live by their rules, to see ourselves and the rest from their points of view, we will come to identify ourselves with the Whole, and to seek its interests. If we do not, I fear that other evolved patterns of our behavior -- our greed and our aggression, our fear and our will to control -- will lead us inexorably to destroy the larger systems that sustain us, or push those systems to a point where it is we who will be destroyed.

I have left many important questions out of this discussion, principally those having to do with social conflict over the control and use of these technologies. I have only tried to sketch a vision of what I would fight for in these coming battles. I believe that we have begun to open new possibilities for the future that are worth working our way towards. The vision must continue to grow.

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